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October 12, 1998

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Mr. Bruce Halstead
US Fish and Wildlife Service
1125 16th St., Room 209
Arcata, California 95521-5582

Dear Mr. Halstead:

I am submitting the enclosed manuscript as a public comment regarding the Pacific Lumber Company Draft Habitat Conservation Plan. The manuscript describes a reanalysis of the Marbled Murrelet at-sea counts collected by C. J. Ralph. I am submitting this manuscript to Conservation Biology; I will invite Dr. Ralph to be a co-author.

In contrast to Dr. Ralph's initial analysis, I find clear and striking declines in the at-sea counts; overall, there is a 7.9% annual decrease in the index of abundance. Of further concern is the 13% annual decrease offshore of the Southern Humboldt Bioregion, indicating that Murrelet population trends in the planning region are much worse than the 4-6% declines considered in the HCP. Given the poor status of this species in the planning region, caution is warranted when considering the impact further habitat reduction will have upon the viability of this species. AS-1

If you have any questions or comments regarding this paper, please contact me via phone at 206-685-6893 or e-mail at astanley@u.washington.edu. Thank you for your time.

Sincerely,

Amanda G. Stanley

Enclosures: 1

A REANALYSIS OF POPULATION TRENDS FOR MARBLED MURRELETS IN NORTHERN CALIFORNIA

RH: Marbled murrelet trend analysis

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ABSTRACT

Indices of abundance from offshore counts conducted in northern California were used to assess population trends of marbled murrelets. Data were collected and originally analyzed using simple linear regression by Ralph and Miller (1995, 1997, 1998). Ralph and Miller (1997, 1998) failed to reject the null hypothesis of zero slope and concluded that marbled murrelets are not declining, with no discussions of the power of their test. In contrast, a likelihood analysis of a simple population model demonstrates a high probability of decline. Different subsets of data were examined to compare trends inshore vs. offshore and north vs. south. The model incorporating all data gives a point estimate of the intrinsic rate of change (r) of -0.0823 for northern California. Trends derived from counts close to shore were not different from counts further off shore. Trends vary by region; declines are moderate near the Oregon border (r = -0.067) and large in the Southern Humboldt Bioregion (r = -0.1425), whereas the Redwood National Park region is stable (r = -0.002).

INTRODUCTION

The Marbled Murrelet (*Brachyramphus marmoratus*) is a swift, elusive seabird with the curious habit of nesting in old-growth forests in the southern portions of its range. Due primarily to extensive logging of these forests in the past 100 years, Marbled Murrelets have declined precipitously. Comparison of historic data (mostly anecdotal) with current population estimates show marked declines and extirpation from much of its original range (Carter and Morrison 1992). The USFWS listed the Marbled Murrelets as threatened in 1992 (USFWS 1992). Unfortunately, these birds are hard to observe and the most basic biology remains mostly unknown (e.g., lifespan, age of first breeding). Nests are difficult to locate, so more complicated parameters such as population size or reproductive success are still only vaguely understood. The best information available for population trends comes from at-sea surveys of murrelets; however, many problems complicate this data and extrapolation from off-shore counts to terrestrial population sizes remains problematic (Ralph and Miller 1995, Becker et al. 1997).

The Marbled Murrelet populations in northern California are of special concern recently due to Pacific Lumber Company's (PALCO) impending Habitat Conservation Plan (HCP). Pacific Lumber owns approximately 200,000 ac of old-growth redwood forest, of which 36,973 ac is listed as critical habitat for Marbled Murrelets by the USFWS (PALCO 1998). PL has proposed allowing the federal government to purchase 7,478 ac containing valuable old-growth to create a new National Park and will set aside an additional 8,500 ac for Marbled Murrelet Conservation Areas in exchange for freedom from further land use restrictions.

The only quantitative data regarding Murrelet population trends in northern California is from Ralph and Miller (1995, 1997, 1998). Transects were surveyed by boat at two distances off shore (800 and 1400 m) for 11 sections of California coastline (a total of 250 km) since 1989.

Ralph and Miller (1998) report the mean count per 2 km and a variation of this mean for each section of coastline from 1989 to 1997. Unfortunately, survey efforts were inconsistent across time and space; not all sections of coastline were surveyed every year. Survey methods are detailed in Ralph and Miller (1995). For additional discussions of this data set and alternate survey methods, see Becker et al (1997).

In a draft report on the effects of different levels of harvest by PALCO, Ralph and Miller (1997) performed a simple trend analysis on their data, using only the mean counts per 2km segment (they did not incorporate the variance of the mean counts). For the 11 stretches of coastline, and the 2 survey distances, they used a simple linear regression to test for significant slopes (a total of 22 analyses). Only 2 of these slopes were significantly different from zero, so they did not reject the null hypothesis of no trend. Ralph and Miller then concluded that murrelets are not declining in California. This could be true; however another alternative is that murrelets are declining, but the decline was not detected (a type II error) (Taylor and Gerrodette 1993; Stanley and Mills In Press). Given the high variance of the data, and the likely deviation from linearity, the chances of a type II error in this case are high. Becker et al. (1997) found the probability of observing a 5% annual decline was <30% when surveying 20 km transects for 5 years. Pooling the data into a single analysis, rather than doing repeated tests of the same data, decreases the probability of a type II error. In the PALCO draft HCP, Ralph and Miller (1998) repeat the trend analysis, this time dividing the California into 3 aggregated sections. Again, most slopes were not significant. Other analysis suggested murrelet populations were stable or increasing in the 2 northern aggregated sections and decreasing in the southern.

The analyses performed by Ralph and Miller make several assumptions: 1) the index of abundance increases linearly with increasing population size; 2) surveys from the 11 sections of coastline represent independent samples of the true slope for the region; 3) there is no year-specific joint observation error and 4) population trends of marbled murrelets are linear. The model used in this paper makes the same assumptions, except for number 4; here, I assume that population trends are exponential.

Thus, my analysis differs from Ralph and Miller (1997, 1998) in three respects: I assume exponential rather than linear population growth, I incorporate the variability of the mean counts, and I pool the data into a single analysis. I use likelihood profiling to examine a simple population model for trends in the index of abundance, examining the differences between inshore and offshore counts as well as differences between northern and southern counts.

ANALYSIS METHODS

Data Use

The raw data used in my model is shown in Appendix 1. The California coastline was divided into 11 sections, varying in length from 4-40 km. Not all sections were surveyed every year, and often sections were surveyed multiple times per year. The mean number of birds seen per 2 km segment per year was reported for each section, along with the variance of that mean. For further explanations of survey methods, see Ralph and Miller (1995, 1997). Data from 1989 to 1997 was reported in the PALCO HCP (Part B.1, pg. 69-71, 1998).

The Model

The underlying model of population growth used by Ralph and Miller (1997, 1998) is linear, of the form:

$$N_t = N_{\text{initial}} + at + \text{error} \qquad (1)$$

where t is the number of years, N is the population size, and a is the slope. Alternately, we know populations change in a multiplicative fashion. Thus a more biologically appropriate model is:

$$N_t = N_{\text{initial}}(e^{rt}) + e^{\text{error}} \tag{2}$$

where r is the intrinsic rate of increase (or decrease). The percent change in the population size each year is e^r - 1. In this data set, we do not have any estimates of population size; we only have an index of abundance. As with Ralph and Miller, I assume that the index changes linearly with true abundance. Thus the index (I) is:

$$I_t = kN_t \tag{3}$$

where k is the proportion of the total population observed; I assume that k is constant from year to year. The model then becomes:

$$kN_t = kN_{\text{initial}}(e^{rt}) + e^{\text{error}}, \text{ or}$$

$$I_t = I_{\text{initial}}(e^{rt}) + e^{\text{error}} \tag{4}$$

As with Ralph and Miller (1997), I assume that each section of coastline represents an independent index of total population size. Thus the time series data for the each section represent multiple estimates of a single slope. Given this assumption, a pooled analysis will yield higher power than separate repeated tests. In my model, each section of coastline has the same value of r but different intercepts (I_{initial}) to account for differences in population density along the coast.

Survey Distances

Ralph and Miller (1997, 1998) report the number of birds seen at 800 and 1400 m off-shore. Studies show that murrelets are most commonly found close to shore (Becker et al. 1997, Ralph and Miller 1995). Initial inspection of the data showed that the 800 m surveys had somewhat lower variability of a single estimate and from year to year. Also, survey effort was more consistent for the 800 m surveys. For this reason, I performed the trend analysis on the 800 m and 1400 m surveys separately and together. Due to variation in the number of abundance estimates for each section (I excluded sections with ≤ 3 years of data or sections with predominantly zero counts), the number of parameters is 13 for the 800m model, 11 for the 1400 m model, and 23 for the combined model.

Aggregated Coastal Sections

Because Marbled Murrelets along the entire northern California coastline probably do not form one contiguous population, trends likely vary by region. Ralph and Miller (1998) divided the coastline into 3 sections based on location of suitable nesting habitat on-shore, section length, and survey effort. I repeated the pooled regression analysis on these same sections, combining data from 800 and 1400 m counts.

Likelihood Profiles

I calculated the maximum likelihood estimate (MLE) and the likelihood profile for the intrinsic growth rate, r. The likelihood (L) of the data given a value of the parameter r, assuming log-normal distribution of the residuals, is given by:

$$L(I_{st}|r) = Exp\left(-\sum_{s=1}^{s=j} \sum_{t=1}^{t=i} \frac{\left(\ln(I_{st}) - \ln(\hat{I}_{st})\right)^2}{2\sigma_{st}^{\ 2}} \right) \tag{5}$$

where I is the observed population index, $\hat{I}$ is the predicted population index, σ^2 is the variance of the abundance estimate, s is the section, and t is the year. The coefficient of variation (standard deviation divided by the mean) is often used in place of σ; in this case, I used the standard error divided by the mean.

Likelihood profiles were generated by varying r systematically and allowing all other parameters to converge to the maximum likelihood estimate (Hilborn and Mangel 1997 pg165).

These values of the likelihood were recorded and normalized to form the profile. Significance of the MLE of r from zero was tested using the likelihood ratio test; the difference in the log of the likelihood when r = MLE to the log of the likelihood when $r = 0$ is distributed as a χ^2 with one degree of freedom (Hilborn and Mangel 1997). Using this ratio test, the 95% confidence intervals are given by values for r for which the likelihood ratio is ≤ 1.92 (the critical value of χ^2 with one degree of freedom divided by 2).

MODEL RESULTS

Survey Distances

The first group of models assumed that all sections of coastline, from the Oregon border to Shelter Cove (see Appendix 1) represented independent estimates of the same slope; i.e., Marbled Murrelets in all of northern California experience the same population trend. I examined how the inclusion of data from different survey distances off-shore affect the likelihood profiles of the slope. All three models (using 800 m, 1400 m, and all survey data) showed slopes significantly different from zero, with maximum likelihood estimates of r ranging from –0.082 to –0.097 (Table 1). The 95% confidence intervals were relatively narrow (especially compared to the large confidence intervals given in Ralph and Miller 1997), with a lower limit of –0.13 and an upper limit of –0.05 (Table 1). The model using the 1400 m survey data produces a somewhat broader likelihood profile, indicating the data are less informative, and a larger rate of change than the 800 m model (Fig. 1). Combining the data from two survey distances into one model yields a MLE for r of –0.0823 (significantly different from zero; $p = 0.0001$). The three MLE estimates of the slope are not significantly different from each other.

Aggregated coastal sections

Trends differed markedly by aggregated coastal section (Fig. 2). Murrelets off shore of Redwood National Park appeared stable (Table 2; $r = -0.002$, not significantly different from zero), while birds in the Northern Del Norte region exhibited moderate declines ($r = -0.068$). Most disturbing is the Southern Humboldt Bioregion, with declines of 13% per year.

DISCUSSION

Median values for the slope for all three survey distance models fall within the upper range of slopes estimated by Beissinger (1995) using demographic data. His model produced yearly rates of decline from 2-12% depending on the parameters used, with the most likely declines from 4-7%. Beissinger further postulated that a 7% decline was highly probable for the Pacific Northwest murrelet populations, based on the low juvenile to adult ratios. This estimate is very similar to the MLE value of the yearly percent change (7.9%) resulting from the combined survey model (Table 1).

As the three models yield similar results, there seems to be no reason to separate the 800 and 1400 m survey data. Therefore the combined model is probably the best in this case, as it utilized all available data. However, because the 800 m model and the combined model give such similar results, sampling at 1400 m might be unnecessary for assessing trends in abundance. If the goal of future surveys is to monitor trends in abundance, effort could be focused on repeatedly sampling at 800 m distance to decrease variance.

Trends in the index of abundance varied substantially in the 3 aggregated coastal sections. Although the accuracy with which these sections represent true boundaries in Murrelet populations remains unknown, the large differences in trend indicate that the status of murrelets could be quite different in the 3 regions. The Murrelet population offshore from the Redwoods National Park region appears stable; an interesting corollary is that relatively little timber was harvested in this region in the study period. In comparison, large timber harvests occurred in the region with the largest declines, the Southern Humboldt Bioregion (PALCO HCP). For example, from 1992 to 1997 PALCO harvested an average of 58 million board feet of old-growth redwood per year (PALCO HCP 1998, IV.B.1 pg. 36). Habitat loss is expected to continue; under the provisions of the draft HCP (PALCO 1998, IV.B.1 pg. 8), 17-23% of currently occupied old growth in the Southern Humboldt Bioregion is available for harvest, including 501 ac of unentered old growth redwood and 8,321 ac of residual old-growth redwood (PALCO HCP IV.B.1 Table 3). The large differences between neighboring regions could be due to range contraction (i.e., as habitat is lost Southern Humboldt, Murrelets move into the Redwoods National Park area).

Several possible factors could confound the observed trend in Marbled Murrelet counts. Probably the most important assumption is that the index of abundance changes linearly with true abundance (eq. 3). It is quite likely the birds are harder to detect at low population sizes such that declines appear more rapid. If this were the case, the true decline might be much less than the observed decline of 7.9%. Another possible confounding factor is the assumption that each section of coastline represents an independent sample of the total population size. Marbled Murrelets are amazing fliers; not only do they make daily journeys of up to 60 km between the sea and their nest, they can also travel many km while on feeding on the water. The sections of coastline used by Ralph and Miller (1995, 1997) vary in length (from 4-40 km) and represent logistical convenience, not biological breaks in murrelet populations. Thus it is quite probable that birds move between these sections of coastline quite freely. This means that samples are not necessarily independent. Another potential problem is a year-specific joint observation error - whereby the proportion of birds observed, k, varies from year to year, depending on observer bias, weather patterns, etc. It is possible (though unlikely) that the observed trend is due to yearly variation in k rather than N. However, these issues cannot be addressed by the available data and require further research.

My analysis shows a clear and striking decline in the counts of Marbled Murrelets off the coast of northern California; when all data are considered, yearly declines are 7.9% with a cumulative decline from 1989-1997 of 48%. Examining trends by region indicates stable populations in the Redwoods National Park region, and declining populations in the Northern Del Norte (6.6% per year) region and the Southern Humboldt Bioregion (13.3% per year). How accurately these trends reflect the true state of nature remains open for debate. Nevertheless, in the absence of any other data to the contrary, we must conclude that Marbled Murrelets are indeed declining in northern California, most likely at an overall rate of 7.9% per year.

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Table 1. Summary of the maximum likelihood estimates of the intrinsic rate of change, *r*, for the pooled trend analyses of Marbled Murrelet at-sea counts from 1989-1997. The different models reflect what data were included - counts made at 800 m off-shore, 1400 m, or both combined. All models assume that all sections of coastline represent independent estimates of the same slope. P-values represent the probability that $r = 0$.

Data Used	MLE of *r*	95% confidence interval	Annual % change	% change between 1989 and 1997	*p*-value
800 m surveys only	-0.08674	-0.06, -.11	-8.308	-50.0386	<<0.0001
1400 m surveys only	-0.09744	-0.065, -0.13	-9.284	-54.137	<<0.0001
800 and 1400 m surveys combined	-0.08233	-0.05, -0.115	-7.903	-48.245	0.0001

Table 2. Summary of the maximum likelihood estimates of the intrinsic rate of change, *r*, for the pooled trend analyses of Marbled Murrelet at-sea counts from 1989-1997. Model assumes Marbled Murrelets in each aggregated coastal section, as defined in Ralph and Miller (1998), form separate populations with different trends. Data from both 800 and 1400 m counts used. P-values represent the probability that $r = 0$.

Aggregated Coastal Section	MLE of *r*	95% confidence interval	Annual % change	% change between 1989 and 1997	*p*-value
Northern Del Norte (Oregon Border to Klamath River - 54 km)	-0.06694	-0.0985, -0.036	-6.556	-41.870	0.003
Redwoods National Park (Klamath River to Trinidad Head - 58 km)	-0.002	-0.047, 0.045	-0.200	-1.587	n.s.
Southern Humboldt Bioregion (Trinidad Head to Shelter Cove - 138 km)	-0.1425	-0.175, -0.11	-13.281	-68.018	<<0.001

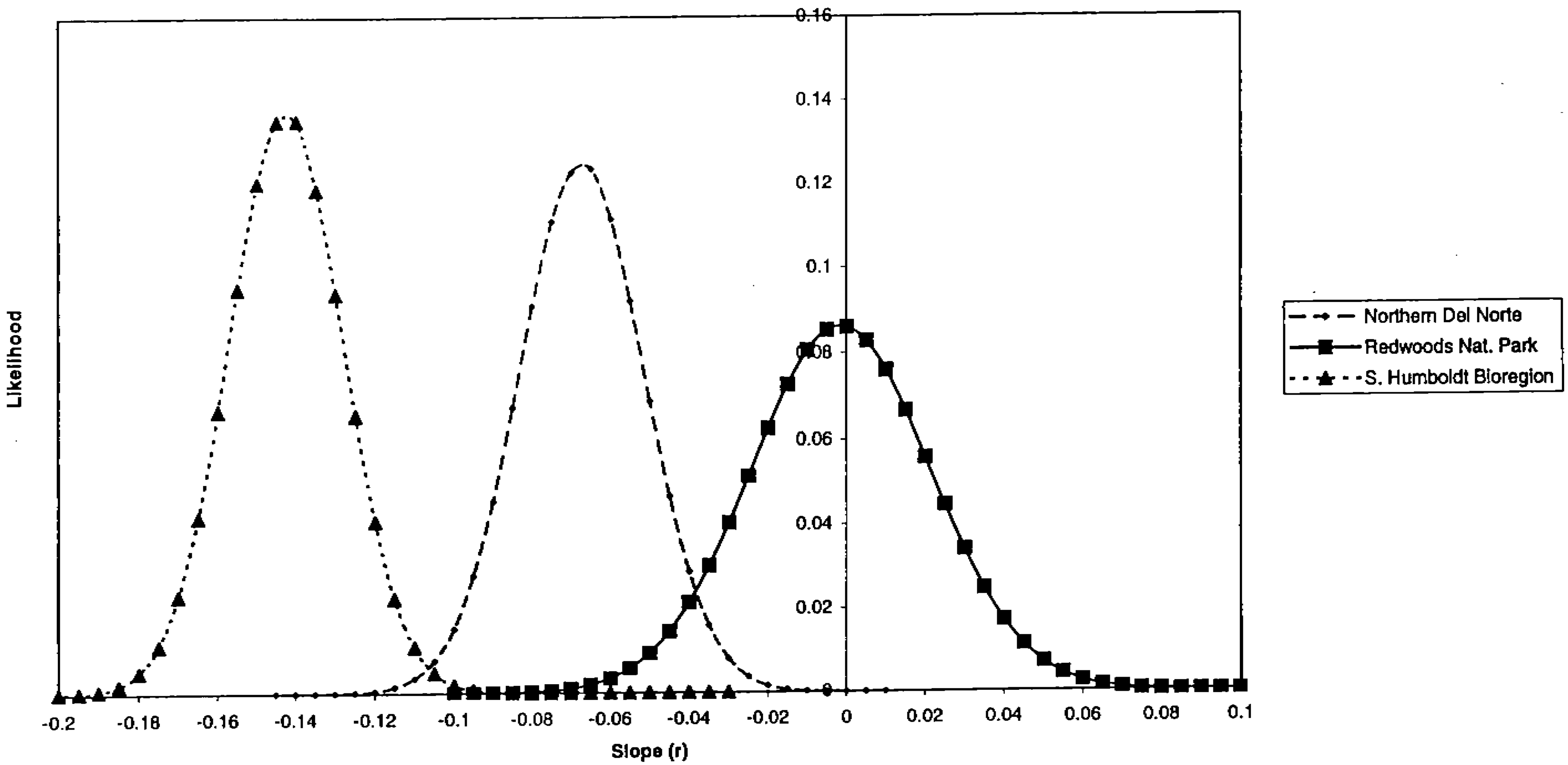
Appendix 1. Marbled Murrelet at-sea survey data, 1989-1997. Collected by Redwoods Biological Laboratory, US National Forest Service. As reported in Ralph and Miller (1995, 1997, 1998).

			800 m from shore				1400 m from shore			
Section*	Number of 2km segments	Year	Total no. of segments surveyed	Total count	Mean number of birds (per 2km)	S.E./ Mean	Total no. of segments surveyed	Total count	Mean number of birds (per 2km)	S.E./ Mean
ORPS	12	1991	24	268	11.17	0.573	24	11	0.46	0.500
		1992	25	167	6.68	0.365	24	42	1.75	0.211
		1993	12	124	10.33	0.439	--	--	--	
		1996	27	94	3.48	0.1925	20	52	2.6	0.3038
		1997	54	525	9.72	0.2222	29	236	8.14	0.2383
PSCB	4	1989	53	89	1.68	0.262	48	64	1.33	0.248
		1990	50	196	3.92	0.416	44	77	1.75	0.309
		1991	40	84	2.1	0.352	36	22	0.61	0.344
		1992	15	28	1.87	0.433	16	9	0.56	0.625
		1993	26	24	0.92	0.533	22	5	0.23	0.478
		1994	12	23	1.92	0.458	11	39	3.55	0.414
		1996	88	131	1.49	0.2013	44	34	0.77	0.5454
		1997	150	537	3.58	0.2039	121	200	1.65	0.2545
CBNC	2	1989	52	424	8.15	0.199	31	113	3.65	0.312
		1990	45	132	2.93	0.287	26	123	4.73	0.353
		1991	36	202	5.61	0.150	32	103	3.22	0.211
		1992	12	104	8.67	0.204	8	69	8.63	0.340
		1993	53	369	6.96	0.198	24	19	0.79	0.456
		1994	14	31	2.21	0.371	5	2	0.4	1.000
		1996	32	109	3.41	0.2317	10	14	1.4	0.5
		1997	51	263	5.16	0.2248	20	136	6.8	0.2
NCKR	9	1990	9	167	18.56	0.548	9	66	7.33	0.280
		1991	97	382	3.94	0.114	111	200	1.8	0.183
		1992	36	198	5.5	0.211	36	132	3.67	0.183
		1993	135	524	3.88	0.149	92	120	1.3	0.300
		1994	41	113	2.76	0.304	24	21	0.88	0.398
		1996	45	135	3	0.2267	22	52	2.36	0.2457
		1997	98	299	3.05	0.2164	105	256	2.44	0.1967
KRBL	20	1991	58	806	13.9	0.126	60	218	3.63	0.179
		1992	50	240	4.8	0.246	80	105	1.31	0.198
		1993	75	935	12.47	0.173	40	310	7.75	0.234
		1995	14	146	10.43	0.226	16	211	13.19	0.174
		1996	8	9	1.12	0.5714	8	4	0.55	0.691
		1997	4	6	1.5	0.5800	7	5	0.71	0.507

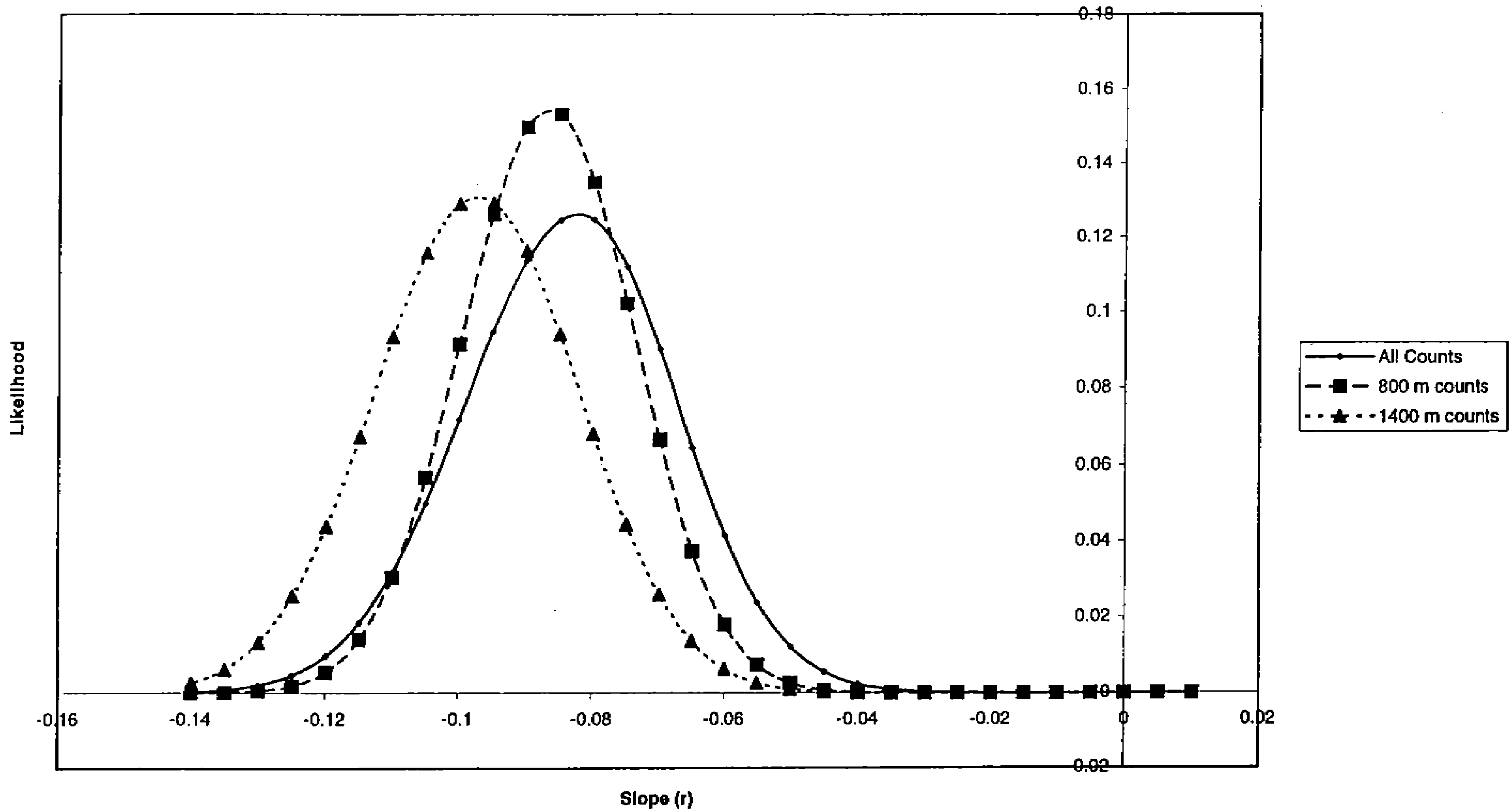
BLTR	9	1989	7	1	0.14	1.000	0	--	--	
		1991	20	60	3	0.310	20	76	3.8	0.379
		1992	30	156	5.2	0.367	34	110	3.24	0.293
		1993	104	472	4.54	0.148	47	96	2.04	0.206
		1994	39	191	4.9	0.206	35	78	2.23	0.377
		1995	77	538	6.99	0.123	27	128	4.74	0.354
		1996	81	188	2.32	0.177	51	24	0.47	0.2551
		1997	94	538	5.72	0.184	80	169	2.11	0.199
TRMR	8	1991	6	33	5.5	0.429	6	32	5.33	0.822
		1992	19	176	9.26	0.190	16	64	4	0.308
		1993	12	113	9.42	0.268	24	81	3.37	0.347
		1994	12	68	5.67	0.423	11	63	5.73	0.192
		1995	20	60	3	0.213	23	83	3.61	0.277
		1996	37	84	2.27	0.207	38	86	2.26	0.208
		1997	29	167	5.76	0.3298	33	97	2.94	0.2143
MRHB	13	1990	27	55	2.04	0.245	28	23	0.82	0.317
		1991	151	407	2.7	0.133	144	269	1.87	0.123
		1992	56	163	2.91	0.148	54	105	1.94	0.294
		1993	101	212	2.1	0.205	116	129	1.11	0.180
		1994	28	29	1.04	0.308	24	21	0.88	0.318
		1995	50	86	1.72	0.186	59	77	1.31	0.252
		1996	103	99	0.96	0.1667	91	44	0.48	0.2292
		1997	168	242	1.44	0.125	140	154	1.1	0.1909
HBTB	4	1989	44	186	4.23	0.149	41	100	2.44	0.180
		1990	61	221	3.62	0.207	62	151	2.44	0.217
		1991	32	113	3.53	0.184	34	64	1.88	0.207
		1992	24	34	1.42	0.387	22	26	1.18	0.356
		1993	27	42	1.56	0.385	40	23	0.57	0.474
		1994	8	20	2.5	0.356	10	11	1.1	0.518
		1995	20	46	2.3	0.252	16	17	1.06	0.340
		1996	64	56	0.88	0.2045	56	6	0.11	5.091
		1997	60	154	2.57	0.2023	56	124	2.21	0.172
TBFC	11	1990	10	36	3.6	0.564	0	--	--	
		1991	60	252	4.2	0.224	63	143	2.27	0.185
		1992	49	82	1.67	0.186	57	110	1.93	0.223
		1993	66	136	2.06	0.170	73	59	0.81	0.235
		1994	27	69	2.56	0.281	16	16	1	0.550
		1995	40	100	2.5	0.320	23	30	1.3	0.323
		1996	80	43	0.54	0.2037	61	20	0.33	0.2727
		1997	79	182	2.3	0.1957	92	128	1.39	0.1727
FCCM	4	1990	1	0	0		0	--	--	
		1991	8	7	0.88	0.727	7	4	0.57	1.000
		1992	13	30	2.31	0.364	12	0	0	
		1993	11	17	1.55	0.277	11	8	0.73	0.616
		1994	2	3	1.5	0.333	1	0	0	

		1995	9	2	0.22	0.682	3	0	0	
		1996	5	3	0.6	1	5	0	0	--
		1997	7	40	5.71	0.6865	8	1	0.13	--
CMSC	29	1991	40	55	1.37	0.394	48	5	0.1	1.000
		1992	50	72	1.44	0.354	55	13	0.24	0.417
		1993	26	13	0.5	0.320	24	0	0	
		1997	51	39	0.76	0.7105	31	8	0.26	0.5769

* ORPS = Oregon border to Point Saint George; PSCB = to Crescent Beach; CBNC = to Nickel Creek; NCKR = to mouth of Klamath River; KRBL = to Big Lagoon; BLTR = to Trinidad; TRMR = to mouth of Mad River; MRHB = to Humboldt Bay; HBTB to Table Bluff; TBFC = to False Cape Mendocino; FCCM = to Cape Mendocino; and CMSC = to Shelter Cove.


Likelihood
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
-0.2
-0.18
-0.16
-0.14
-0.12
-0.1
-0.08
-0.06
-0.04
-0.02
0
0.02
0.04
0.06
0.08
0.1
Slope (r)
Northern Del Norte
Redwoods Nat. Park
S. Humboldt Bioregion

LIST OF FIGURES



Likelihood
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.16
-0.14
-0.12
-0.1
-0.08
-0.06
-0.04
-0.02
0
0.02
Slope (r)
All Counts
800 m counts
1400 m counts